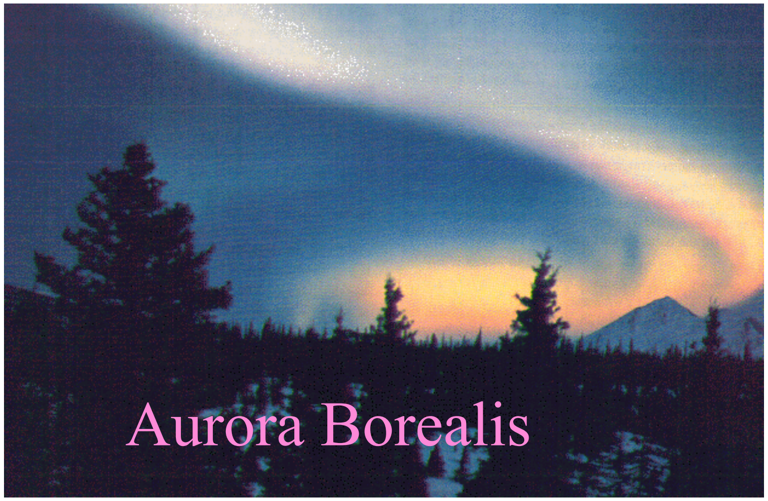
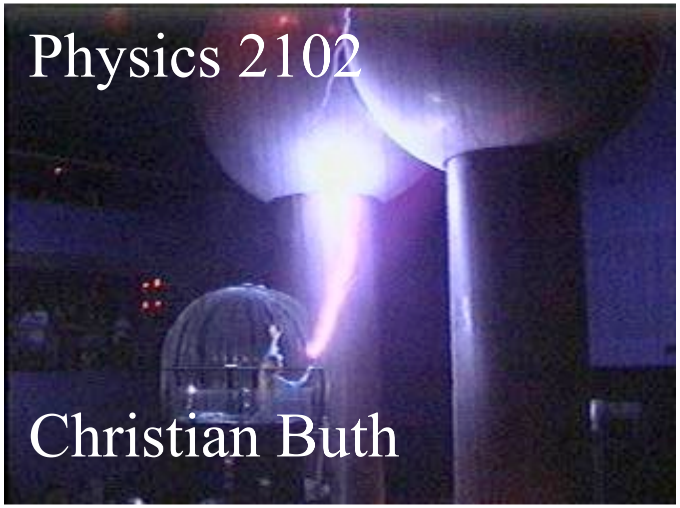


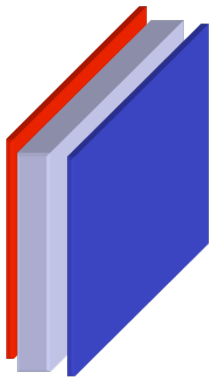


Physics 2102
Lecture 20

Version: 03/04/2009

Review Lectures 11-19

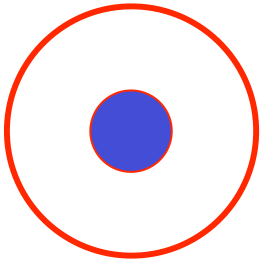
Lecture 11: Capacitance 1



- Any two charged conductors form a **capacitor**
- **Capacitance**: $C = Q/V$
- Simple Capacitors:

Parallel plates: $C = \varepsilon_0 A/d$

Spherical: $C = 4\pi \varepsilon_0 ab/(b-a)$



Lecture 12: Capacitance 2

- **Capacitors in series**: same charge, not necessarily equal potential; equivalent capacitance $1/C_{eq}=1/C_1+1/C_2+\ldots$
- **Capacitors in parallel**: same potential; not necessarily same charge; equivalent capacitance $C_{eq}=C_1+C_2+\ldots$
- **Energy in a capacitor**: $U=Q^2/2C=CV^2/2$
- **Energy density**: $u=\varepsilon_0 E^2/2$

Lecture 13: Current and Resistance 1

- Capacitor with a dielectric: **capacitance increases** $C' = \kappa C$
- Dielectric consists of molecules which **align** in field; yields **surface charges** which reduce the field between the plates
- Battery creates **potential difference** which leads to a **current** in a closed circuit
- **Current arrow** is drawn in direction in which **positive** charge carriers would move
- **Drift speed**: v_d speed at which electrons move to establish a current

$$v_d = \frac{i}{nAe} = \frac{J}{ne}$$

$$\vec{J} = ne\vec{v}_d$$

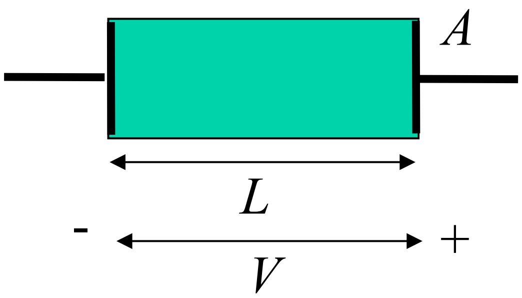
Lecture 14: Current and Resistance 2

- A **resistor** is a conductor whose resistance does **not** change with the voltage

$$R \equiv \frac{V}{i} \qquad R = \rho \frac{L}{A}$$

- A linear $I - V$ curve is said to be **Ohmic** otherwise non-Ohmic
- **Resistivity** is associated with a **material**, **resistance** with respect to a **device** constructed with the material
- Conductivity : $\sigma = \dfrac{1}{\rho}$
- Resistivity depends on temperature: $\rho = \rho_0 (1+\alpha (T\text{-}T_0))$
- Reason for resistance: conduction electrons **collide** with stationary ionic lattice

Resistance of a Rod



$$E = \frac{V}{L}, \qquad J = \frac{i}{A}$$

$$\rho = \frac{V/L}{i/A} = R\frac{A}{L}$$

$$\boxed{R = \rho\frac{L}{A}}$$

Makes sense! Longer → More resistance

For a given material: Thicker → Less resistance

Lecture 15: DC Circuits 1

- **Electromotive fore devices** (emf) maintain a potential between their terminals

- **Kirchhoff's loop rule** (KLR):

KLR : The algebraic sum of the changes in potential encountered in a complete traversal of any loop in a circuit is equal to zero.

- When walking through an emf, add $+\mathcal{E}$ if you flow with the current or $-\mathcal{E}$ otherwise

- When walking through a resistor, add $-iR$, if flowing with the current or $+iR$ otherwise

Lecture 16: DC Circuits 2

- The potential of ideal emf devices does not depend on the current; real emf devices have **internal resistance**
- **Kirchhoff's junction rule:**

KJR : The sum of the currents entering any junction is equal to the sum of the currents leaving the junction.

- **Resistors in parallel** replace by equivalent resistance

$$\frac{1}{R_{eq}} = \sum_{j=1}^{n} \frac{1}{R_j}$$

- **Resistors in series** replace by equivalent resistance

$$R_{eq} = \sum_{j=1}^{n} R_j$$

- **Ammeter** measures current; **voltmeter** measures voltage

Lecture 17: DC circuits, RC circuits

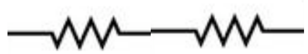
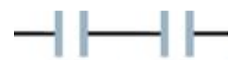
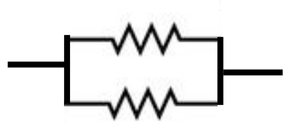
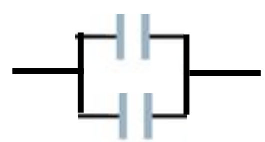
- Technique to **solve multiloop circuits**
    1. Simplify "compile" circuits
    2. Apply loop rule
    3. Equations to unknowns

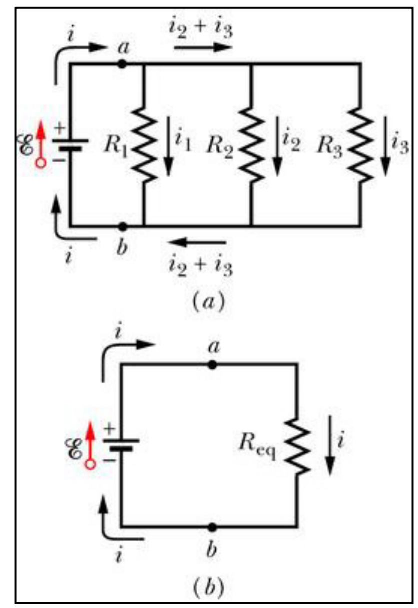
- **RC circuits**: simple circuit with time-varying current; time constant is $\tau = RC$

- **Charging** a capacitor: $q(t) = CE(1-e^{-t/RC})$

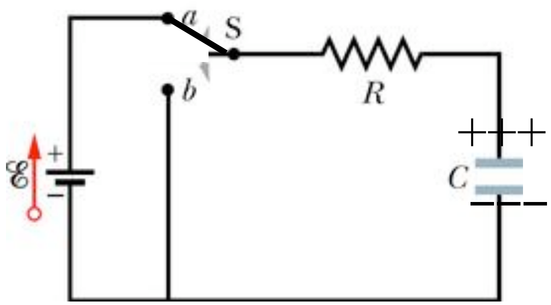
- **Discharging** a capacitor: $q(t)=CEe^{-t/RC}$

Step I: Simplify "Compile" Circuits

	Resistors	**Capacitors**
		
Key formula:	$V=iR$	$Q=CV$
In series:	same current	same charge
	$R_{eq}=\sum R_j$	$1/C_{eq}=\sum 1/C_j$
		
In parallel:	same voltage	same voltage
	$1/R_{eq}=\sum 1/R_j$	$C_{eq}=\sum C_j$
		

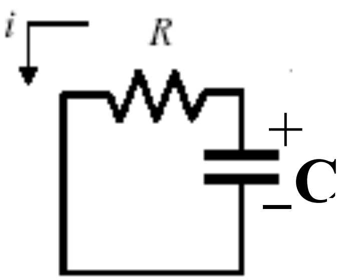


RC Circuits: Discharging a Capacitor



Assume the switch has been closed on a for a long time: the capacitor will be charged with Q=CE.

Then, close the switch on *b*: charges find their way across the circuit, establishing a current.

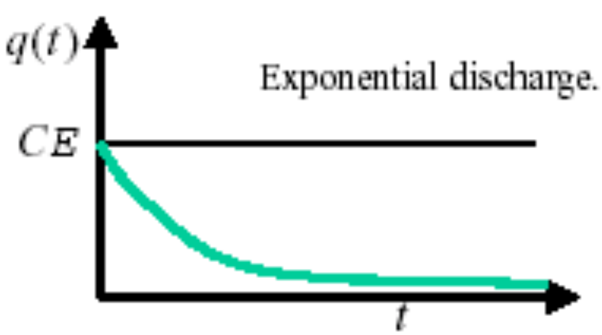


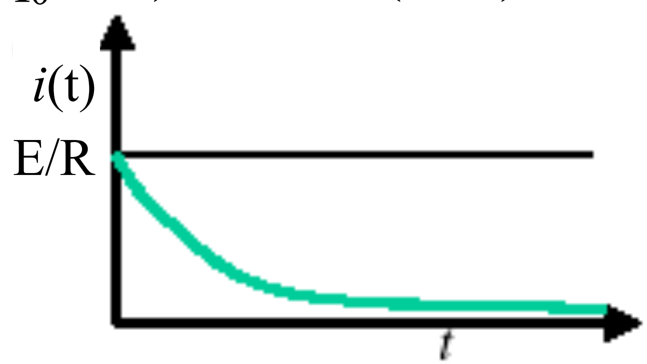
$V_R + V_C = 0$

$-i(t)R - q(t)/C = 0 \Rightarrow (dq/dt)R + q(t)/C = 0$

Solution: $q(t) = q_0 e^{-t/RC} = CEe^{-t/RC}$

$i(t) = dq/dt = (q_0/RC)\, e^{-t/RC} = (E/R)\, e^{-t/RC}$





Lecture 18: Magnetic fields 1

- Magnetic fields **exert forces** on moving charges $\boldsymbol{F}_B = q\,\boldsymbol{v} \times \boldsymbol{B}$: the force is **perpendicular** to the field and the velocity
- Magnetic field lines are used to **visualize** magnetic fields
- Magnetic field $\boldsymbol{B}$ has SI unit **tesla**
- **Right hand rule** for vector products (cross products)
- **Cathode ray tube** crossed electric and magnetic fields; lead to discovery of electron
- **Hall effect** reveals that charge carriers in metals are negative (electrons)

Lecture 19: Magnetic fields 2

- **Hall effect** reveals that charge carriers in metals are negative (electrons)

- Charged particle with velocity perpendicular to magnetic field on **circular path**

$$r = \frac{mv_\perp}{|q|B} \qquad T = \frac{2\pi m}{|q|B}$$

- Generally linear and circular motion superimposed: a **helix** with radius r and **pitch** $p = Tv_{\parallel}$

- Charged particles trapped in **magnetic bottle**; natural phenomenon: **aurora borealis**

- **Cyclotrons and synchrotrons** to accelerate electron and protons


Remains to be said:
May the Force be with You!